#50

LIBRARY
JUN 9 1987
National Marine Fisheries
2570
Honolulu, Hawaii

NOAA Technical Report NMFS 50

March 1987

Preparation of Acetate Peels of Valves from the Ocean Quahog, *Arctica islandica*, for Age Determinations

John W. Ropes

NOAA
Tech.
Rept.
NMFS
50

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service

NOAA TECHNICAL REPORT NMFS

The major responsibilities of the National Marine Fisheries Service (NMFS) are to monitor and assess the abundance and geographic distribution of fishery resources, to understand and predict fluctuations in the quantity and distribution of these resources, and to establish levels for their optimum use. NMFS is also charged with the development and implementation of policies for managing national fishing grounds, development and enforcement of domestic fisheries regulations, surveillance of foreign fishing off United States coastal waters, and the development and enforcement of international fishery agreements and policies. NMFS also assists the fishing industry through marketing service and economic analysis programs, and mortgage insurance and vessel construction subsidies. It collects, analyzes, and publishes statistics on various phases of the industry.

The NOAA Technical Report NMFS series was established in 1983 to replace two subcategories of the Technical Reports series: "Special Scientific Report—Fisheries" and "Circular." The series contains the following types of reports: Scientific investigations that document long-term continuing programs of NMFS; intensive scientific reports on studies of restricted scope; papers on applied fishery problems; technical reports of general interest intended to aid conservation and management; reports that review in considerable detail and at a high technical level certain broad areas of research; and technical papers originating in economics studies and from management investigations. Since this is a formal series, all submitted papers receive peer review and those accepted receive professional editing before publication.

Copies of NOAA Technical Reports NMFS are available free in limited numbers to governmental agencies, both Federal and State. They are also available in exchange for other scientific and technical publications in the marine sciences. Individual copies may be obtained from: U.S. Department of Commerce, National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161. Although the contents have not been copyrighted and may be reprinted entirely, reference to source is appreciated.

13. Guidelines for reducing porpoise mortality in tuna purse seining, by James M. Coe, David B. Holts, and Richard W. Butler. September 1984, 16 p.

14. Synopsis of biological data on shortnose sturgeon, *Acipenser brevirostrum* LeSueur 1818, by Michael J. Dadswell, Bruce D. Taubert, Thomas S. Squiers, Donald Marchette, and Jack Buckley. October 1984, 45 p.

15. Chaetognatha of the Caribbean sea and adjacent areas, by Harding B. Michel. October 1984, 33 p.

16. Proceedings of the Ninth and Tenth U.S.-Japan Meetings on Aquaculture, by Carl J. Sindermann (editor). November 1984, 92 p.

17. Identification and estimation of size from the beaks of 18 species of cephalopods from the Pacific Ocean, by Gary A. Wolff. November 1984, 50 p.

18. A temporal and spatial study of invertebrate communities associated with hard-bottom habitats in the South Atlantic Bight, by E. L. Wenner, P. Hinde, D. M. Knott, and R. F. Van Dolah. November 1984, 104 p.

19. Synopsis of biological data on spottail pinfish, *Diplodus holbrooki* (Pisces: Sparidae), by George H. Darcy. January 1985, 11 p.

20. Ichthyoplankton of the Continental Shelf near Kodiak Island, Alaska, by Arthur W. Kendall, Jr., and Jean R. Dunn. January 1985, 89 p.

21. Annotated bibliography on hypoxia and its effects on marine life, with emphasis on the Gulf of Mexico, by Maurice L. Renaud. February 1985, 9 p.

22. Congrid eels of the eastern Pacific and key to their Leptocephali, by Solomon N. Raju. February 1985, 19 p.

23. Synopsis of biological data on the pinfish, *Lagodon rhomboides* (Pisces:Sparidae), by George H. Darcy. February 1985, 32 p.

24. Temperature conditions in the cold pool 1977-81: A comparison between southern New England and New York transects, by Steven K. Cook. February 1985, 22 p.

25. Parasitology and pathology of marine organisms of the world ocean, by William J. Hargis, Jr. (editor). March 1985, 135 p.

26. Synopsis of biological data on the sand perch, *Diplectrum formosum* (Pisces: Serranidae), by George H. Darcy. March 1985, 21 p.

27. Proceedings of the Eleventh U.S.-Japan Meeting on Aquaculture, Salmon Enhancement, Tokyo, Japan, October 19-20, 1982, by Carl J. Sindermann (editor). March 1985, 102 p.

28. Review of geographical stocks of tropical dolphins (*Stenella* spp. and *Delphinus delphis*) in the eastern Pacific, by William F. Perrin, Michael D. Scott, G. Jay Walker, and Virginia L. Cass. March 1985, 28 p.

29. Prevalence, intensity, longevity, and persistence of *Anisakis* sp. larvae and *Lacistorhynchus tenuis* metacestodes in San Francisco striped bass, by Mike Moser, Judy A. Sakanari, Carol A. Reilly, and Jeannette Whipple. April 1985, 4 p.

30. Synopsis of biological data on the pink shrimp, *Pandalus borealis* Kröyer, 1838, by Sandra E. Shumway, Herbert C. Perkins, Daniel F. Schick, and Alden P. Stickney. May 1985, 57 p.

NMFS Honolulu Library
00000000004740

31. Shark catches from selected fisheries off the U.S. east coast, by Emory D. Anderson, John G. Casey, John J. Hoey, and W. N. Witzell. July 1985, 22 p.

32. Nutrient Distributions for Georges Bank and adjacent waters in 1979, by A. F. J. Draxler, A. Matte, R. Waldhauer, and J. E. O'Reilly. July 1985, 34 p.

33. Marine flora and fauna of the Northeastern United States. Echinodermata: Echinoidea, by D. Keith Serafy and F. Julian Fell. September 1985, 27 p.

34. Additions to a revision of the shark genus *Carcharhinus*: Synonymy of *Aprionodon* and *Hypoprion*, and description of a new species of *Carcharhinus* (Carcharhinidae), by J. A. F. Garrick. November 1985, 26 p.

35. Synoptic review of the literature on the Southern oyster drill *Thais haemastoma floridana*, by Philip A. Butler. November 1985, 9 p.

36. An egg production method for estimating spawning biomass of pelagic fish: Application to the northern anchovy, *Engraulis mordax*, by Reuben Lasker (editor). December 1985, 99 p.

37. A histopathologic evaluation of gross lesions excised from commercially important North Atlantic marine fishes, by Robert A. Murchelano, Linda Despres-Patanjo, and John Ziskowski. March 1986, 14 p.

38. Fishery atlas of the northwestern Hawaiian Islands, by Richard N. Uchida and James H. Uchiyama (editors). September 1986, 142 p.

39. Survey of fish protective facilities at water withdrawal sites on the Snake and Columbia Rivers, by George A. Swan, Tommy G. Withrow, and Donn L. Park. April 1986, 34 p.

40. Potential impact of ocean thermal energy conversion (OTEC) on fisheries, by Edward P. Myers, Donald E. Hoss, Walter M. Matsumoto, David S. Peters, Michael P. Seki, Richard N. Uchida, John D. Ditmars, and Robert A. Paddock. June 1986, 33 p.

41. A stationary visual census technique for quantitatively assessing community structure of coral reef fishes, by James A. Bohnsack and Scott P. Bannerot. July 1986, 15 p.

42. Effects of temperature on the biology of the northern shrimp, *Pandalus borealis*, in the Gulf of Maine, by Spencer Apollonio, David K. Stevenson, and Earl E. Dunton, Jr. September 1986, 22 p.

43. Environment and resources of seamounts in the North Pacific, by Richard N. Uchida, Sigeiti Hayasi, and George W. Boehlert (editors). September 1986, 105 p.

44. Synopsis of biological data on the porgies, *Calamus arctifrons* and *C. proridens* (Pisces: Sparidae), by George H. Darcy. September 1986, 19 p.

45. Meristic variation in *Sebastes* (Scorpaenidae), with an analysis of character association and bilateral pattern and their significance in species separation, by Lo-chai Chen. September 1986, 17 p.

46. Distribution and relative abundance of pelagic nonsalmonid nekton off Oregon and Washington 1979-84, by Richard D. Brodeur and William G. Pearcy. December 1986, 85 p.

NOAA Technical Report NMFS 50

Preparation of Acetate Peels of Valves from the Ocean Quahog, *Arctica islandica*, for Age Determinations

John W. Ropes

March 1987

U.S. DEPARTMENT OF COMMERCE
Malcolm Baldrige, Secretary
National Oceanic and Atmospheric Administration
Anthony J. Calio, Administrator
National Marine Fisheries Service
William E. Evans, Assistant Administrator for Fisheries

Library
NOAA, National Marine Fisheries Service
SWFC Hon... ...ory F/SWC2
2570 ...
Hono...

The National Marine Fisheries Service (NMFS) does not approve, recommend or endorse any proprietary product or proprietary material mentioned in this publication. No reference shall be made to NMFS, or to this publication furnished by NMFS, in any advertising or sales promotion which would indicate or imply that NMFS approves, recommends or endorses any proprietary product or proprietary material mentioned herein, or which has as its purpose an intent to cause directly or indirectly the advertised product to be used or purchased because of this NMFS publication.

CONTENTS

Introduction 1

Procedures 2

Processing-time economies 3

Identity of annuli 3

Summary 4

Citations 5

Preparation of Acetate Peels of Valves from the Ocean Quahog, *Arctica islandica*, for Age Determinations

JOHN W. ROPES
Northeast Fisheries Center
Woods Hole Laboratory
National Marine Fisheries Service, NOAA
Woods Hole, MA 02543

ABSTRACT

Techniques are described for preparing acetate peels of sectioned valves of ocean quahogs, *Arctica islandica*, for age determinations. The respective sequence of preparation begins by sectioning left valves oriented to include a single hinge tooth, bleaching to remove the heavy periostracum, embedding the valves in an epoxy resin, grinding and polishing the embedments to a high luster, etching the exposed cut valve surfaces, and applying sheet acetate with acetone. Annuli are clearly defined relative to growth increments in the peel preparations for all sizes and ages of ocean quahogs.

INTRODUCTION

Bivalve molluscs have historically been aged by examining the external valve surfaces for dark growth "rings" or "bands" that form as an annual periodic event (Weymouth 1923; Stevenson and Dickie 1954; Wilbur and Owen 1964; Merrill et al. 1966; Feder and Paul 1974). Ring formation has been associated with factors having probable effect on the metabolism of growth, such as extrinsic environmental conditions (temperature) or intrinsic conditions (spawning). In applying the method to some species, however, conflicting or incomplete age estimates may be obtained. This is particularly true for the ocean quahog, *Arctica islandica* Linné, a species with a potentially very long life history (Thompson et al. 1980a). Small ocean quahogs (<60 mm in shell length) often exhibit definite external rings useful in measuring growth and determining age. Some of the rings formed in the earliest years of the life of a large ocean quahog may be discernible, but those near the ventral valve margin usually become crowded together, and often the overall periostracum is black in color. Separation of the rings is impossible, even under magnification, and erosion of the shell surface in the umbonal area often obliterates the youngest rings.

In some bivalve species, internal narrow dark growth lines (hereafter termed annuli) alternating with broad light growth-increment deposits are seen in the broken edges of valves. The annuli have continuity with rings on the external valve surface. Development of diamond-impregnated saw blade equipment has greatly facilitated sectioning bivalve shells in a directed manner for an examination of the accretion of shell layers from the beginning of their formation at the umbo to the ventral margin. Although sectioning the valve is a time-consuming procedure, it permits an examination of the internal depositional features. These tend to be much less affected by destructive external environmental conditions impacting on the valve surfaces and, thus, a record of growth is preserved intact. Annual microstructural deposits may also occur in other parts of the shell that can be prepared for examination by fairly rapid methods, e.g., the chondrophores of the surf clam, *Spisula solidissima* (Dillwyn) (Ropes and O'Brien 1979).

Simply cutting the valves of a bivalve may not expose well-defined annuli, due to variations in the microstructure of the shell deposits. Such is the case for ocean quahogs. Kummel and Raup (1965) developed techniques for fossil bivalves involving preparation of the cut valve surfaces and transfer of the microstructural details onto sheet acetate.

The objectives in the development of procedures for ocean quahogs were that age/growth characteristics be determined precisely and efficiently. Assessment surveys of the population can provide large numbers of specimens for analysis, from 1,500-2,500 per survey. This paper describes procedures developed at the Northeast Fisheries Center for the preparation of acetate peels of sectioned bivalves. It is the only known technique at present for accurately determining the age of ocean quahogs, and more clearly exposes annuli in younger specimens than examination of the external valve surface. It also has potential application for other difficult-to-age bivalves.

PROCEDURES

Sample information is recorded for each ocean quahog preliminary to preparing the valves for aging. A sequential code number is inscribed on each valve of a pair, single valve, or piece of a valve. Measurements of length (the longest antero-posterior dimension), height (the deepest dorso-ventral dimension), width (the widest lateral dimension), and dry weight are made of paired, whole valves to 0.1 mm with vernier calipers, and weight to 0.1 g. Figure 1 shows the features of an ocean quahog valve for orientation purposes in measuring and sectioning operations.

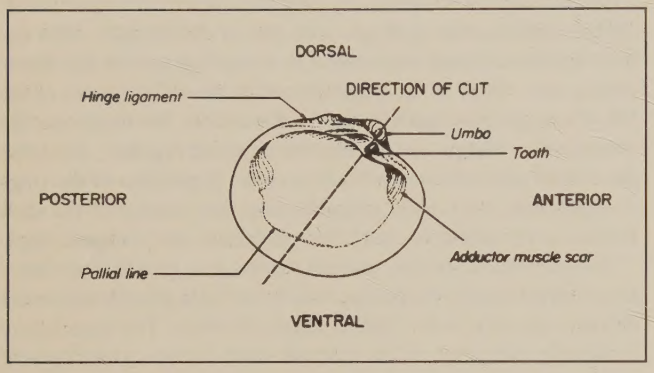

Figure 1—Sketch of internal valve features and direction of cut (dashed line) to completely section the left valve of an ocean quahog, *Arctica islandica*. The anterior portion of the valve is retained for subsequent processing.

The left valve of a pair is selected for sectioning, since it has a single prominent tooth in the hinge. The tooth contains annuli for exposure during the sectioning operation of the valve. Each valve is marked on the ventral margin at a point from the posterior end equal to one-third of the valve length. This orients sectioning through the umbo and parallel to the broadest tooth surface.

The valve is fastened firmly to the adjustable arm holder of the saw unit by a sticky, putty-like material (Slab-Stick) with its concave, inner surfaces toward a diamond-impregnated saw blade (Fig. 2, Table 1). The valve is oriented with the tooth toward the front of the saw machine and is positioned to cut from the mark on the ventral margin through the middle of the tooth, or immediately beside the posterior edge of the tooth. This latter orientation is necessary for small valves, since the small-sized tooth would be destroyed by the cut of the saw blade. Upon nearing completion of the cut through the valve, thumb pressure applied beneath the adjustable arm holder lessens the weight of the valve, and avoids breakage and saw blade damage. This procedure minimizes such problems by focusing the operator's attention on the cutting action of the saw. The anterior portion of the valve is saved for later treatment. About 7-8 medium sized (60-70 mm long) or 3-4 large sized (100+ mm) *Arctica* can be cut per hour at 300 rpm of the saw blade. No more than the heaviest weight (150 g) provided for the saw machine is used on the adjustable arm for large clams; the medium weight (75 g) for medium clams; and the lightest weight (25 g) for small clams. Excessive weight is avoided, since this can warp the blade or break the valve.

Aragonitic granules (a form of calcium carbonate) in the periostracum of ocean quahogs dissolve during a later etching step, leaving voids at the edge of valve peel preparations that distort the peel image (Ropes et al. 1984). This covering is therefore removed by immersing the sectioned cut surfaces in a shallow solution of full-strength household bleach for a few hours (Table 1). Each valve is periodically inspected and removed as soon as the periostracum is dissolved away. A rinse in tap water completes this step. Precautionary procedures for minimizing the destruction of ultrastruc-

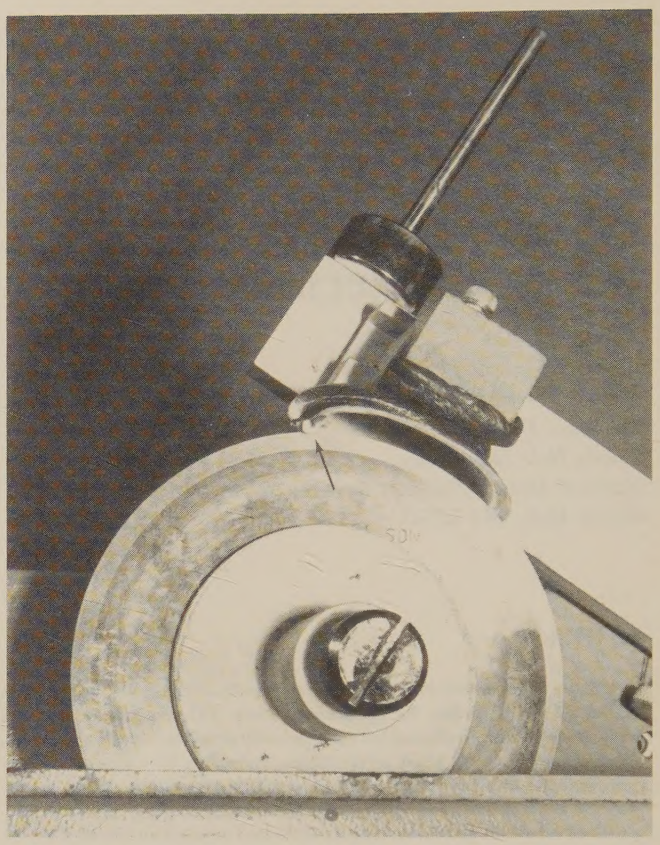

Figure 2—Close-up view of the left valve of an ocean quahog, *Arctica islandica*, fastened to the adjustable arm of the saw unit and oriented with the tooth (arrow) beside the diamond blade.

Table 1—Sources of apparatus and materials.

Source	Apparatus or material
Buehler Ltd. 41 Waukegan Road P.O. Box 1 Lake Bluff, IL 60044	Isomet Low Speed Saw Diamond Wafering Blades (4″ & 5″ dia., high concentration)
Commercial Plastics & Supply Corp. 352 McGrath Highway Sommerville, MA 02143	Di-acetate sheets 19×24×0.005″ thick
Miller-Stephenson Chemical Co., Inc. P.O. Box 950 Danbury, CT 06810	Epon 815 and DTA hardener
Pigment Dispersions, Inc. 54 Kellogg Court P.O. Box 412 Edison, NJ 08818	#2301 blue pigment
Raytech Industries, Inc. P.O. Box 6 Stafford Springs, CT 06075	Hustler Vibrating Lap 15″ dia. Slab-Stick Ray-Tilt 6″ Gem Maker Grinding Machine
Local markets	Bleach (sodium hypochlorite ca. 5.25%) Norton, Tufbak, Durite, Waterproof paper, Closekote, Silicon Carbide

tural details by extended exposure of molluscan shells to bleach have been outlined by Carriker (1979).

Some grinding of the cut surfaces is advisable before further processing, if saw marks or other unwanted blemishes are evident, or if the saw cut was not close to the tooth. Careful handling is important in this step to minimize chipping of the cut valve edge. Carbide paper of two successively finer grits (240 and 400) is used for grinding and water is used on the paper to wash away particles (Table 1). About 15 min per specimen may be spent in this grinding operation. After thoroughly rinsing the valves in tap water, they are allowed to dry.

An epoxy resin is used for support of the valves during subsequent polishing operations (Table 1). The resin, hardener, and a colored pigment are carefully but thoroughly mixed (ca. 1 min), avoiding the introduction of bubbles, and in small amounts (50-75 mL) to minimize heat due to an exothermic reaction between the resin and hardener. The pigment added to the clear epoxy serves as a background, contrasting color with the white valves in a later grinding operation. The mixed epoxy is poured into plastic- or paraffin-coated molds to a depth of about ½ cm. When lowering a valve into the epoxy, the cut surface is pressed down onto the mold bottom to force out bubbles. Some bubbles may adhere to the valve surfaces, and if they are not removed may distort the acetate peel impression. These can be dislodged with the stirring stick used to mix the epoxy, but subjecting the set-up to the pressure of a vacuum chamber for an hour usually evacuates bubbles that may not be easily detected. After an overnight hardening period, the embedded valves are removed from the molds.

Three successively finer grits (240, 400, and 600) of carbide paper are then used to obtain a flat, smooth surface on the embedded cut surfaces of the valves. Most of the grinding is done with the 240 grit paper to remove epoxy and to expose the broadest area of the tooth; the finer grits (400 and 600) are used to minimize scratches from the coarser grit papers. Hand grinding tends to produce optimal results, because frequent inspection can be made of the progress of grinding; however, a grinding machine has proven to be faster (Table 1). Usually only the 240 grit is used on the machine to remove excess epoxy, followed by hand grinding to remove the circular and deep scratches that may have been produced by the machine. About 15-30 min per specimen may be spent exposing the tooth and valve surfaces. The pigment in the epoxy helps in determining the desired level of exposure of the cut surface. This initial grinding prepares the embedded valves for the final polishing steps.

A blemish-free, high-gloss surface on the cut valve surfaces is required and is produced on a vibrating lap machine in two steps (Table 1). In the first step, the pad lining the bottom of an attachable pan is flooded with tap water and drained. After clamping the pan on the machine, the pad is charged with about one teaspoon of #2 medium grit powder, the specimen is placed on the pad, and the machine is turned on. During a 1-2 hour period, the specimen is occasionally removed, rinsed off in tap water, damp-dried, and inspected for a moderate sheen. In the second step, the specimen is transferred to a similar pan flooded with water, but the pad is charged with fine grit (#3) powder. The valves are polished an additional 1-2 hours; more grit powder added after one hour hastens polishing. A final high gloss is most evident on the cut valve surface, but less so on the epoxy surface. A thorough washing in tap water removes traces of grit.

The polished block face is then placed in or flooded with a 1% HCl solution for one minute to etch the valve surfaces and rinsed in tap water, taking care not to damage the etched surfaces. After drying the block, code numbers for each valve are scribed with a carbide-tipped pen into the epoxy near the cut valve surfaces. These numbers are automatically transcribed onto the acetate peel during the next step.

Acetate peels are made by supporting the etched block with the surfaces uppermost and level. An acetate sheet is laid over the surface and a binder clip is used to hold it at one end (Table 1). The other end of the sheet is then lifted and acetone is pipetted onto the specimen while lowering the sheet. Acetone must flood completely between the sheet and block surface without bubbles for a successful peel. After draining of excess acetone, the whole block is turned over, laid on a pad of paper, and pressed for about one minute. After a one-hour drying period, the acetate is peeled off.

The peels are sandwiched between glass slides for examination under a light compound microscope, although the image may also be projected onto the screen of a fish-scale microprojector. Additional peels can be made by simply applying a new sheet of acetate and acetone to the specimen. A sheet of acetate left on the block protects the specimen from damage.

Processing-time economies

Sectioning the valves before embedding them is a departure from the technique described by Kennish et al. (1980), since it permits more certain orientation of a valve over the saw blade. It also speeds sectioning because there is no epoxy to cut through. Kennish et al. (1980) warned that unembedded valves may be fractured. Such damage to ocean quahogs was minimized by careful handling of the fairly robust valves. Individuals as small as 10 mm in shell length have been successfully prepared for aging.

Other modifications economize on time and materials, since there is a need to be efficient in the preparation process. Two saws have been used during the sectioning step. Unembedded, sectioned valves were polished and etched in an attempt to eliminate the embedding step, but the peels were distorted by acetate melting over the valve edges. This resulted in incomplete peel images at the valve edges. To further speed the process, groups of valves are placed in the bleach solution. Sectioned valves are lowered edge-first into a shallow depth of epoxy rather than embedding a whole valve. This permits grouping more than one valve (up to 3-4) in a single mold. The group of embedded valves is also more easily handled during the later grinding/polishing, etching, and peel steps.

Identity of annuli

Acetate peels of many marked ocean quahogs recovered in subsequent years have been prepared, since these individuals add significant support to the hypothesis that annuli are accreted annually and make possible the identification of annuli (Thompson et al. 1980a, b; Jones 1980; Bennett et al. 1982; Turekian et al. 1982; Murawski et al. 1982; Ropes et al. 1984). A large ocean quahog valve marked in 1978 and recovered in 1983 is shown in Figures 3a and b. The black periostracum has been peeled away in the marked area to reveal the lack of discernible growth after the clam had been marked (measurement indicated growth of only 0.7 mm). External rings were not evident in the periostracal layer or annuli beneath it. In contrast, a small ocean quahog valve marked and recaptured during the same years displayed visible external rings in the periostracal layer and substantial growth (14.4 mm) after marking (Fig. 4a).

A photomicrograph of the acetate peel produced by our method of sectioning, embedding, polishing, and etching the ventral valve margin of the large specimen shows an indentation from the mark-

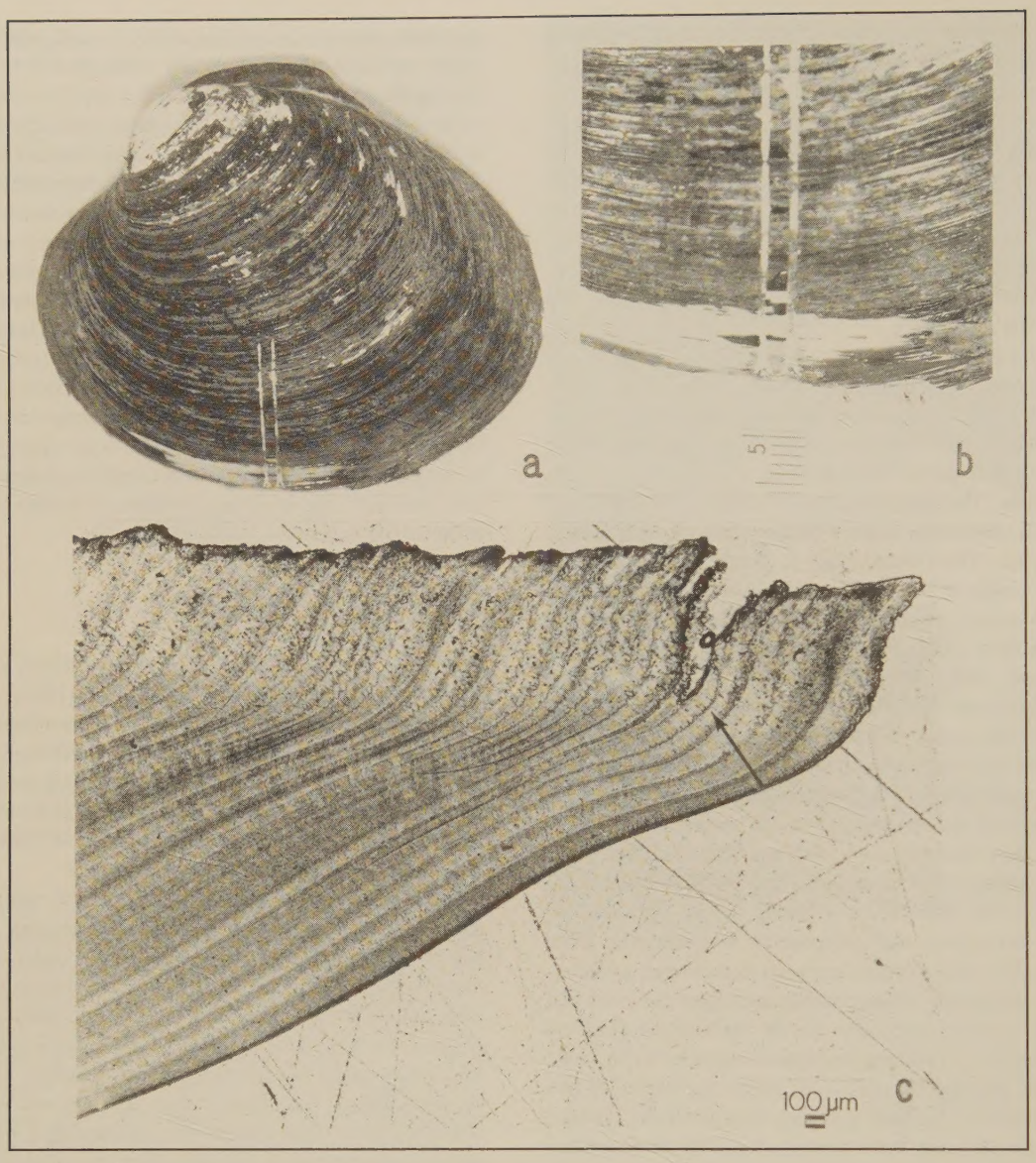

Figure 3—a) A 110-mm shell length ocean quahog, *Arctica islandica*, marked in 1978 and recaptured in 1983. b) Enlargement of the paired parallel notch marks made at the ventral valve margin. Note that growth (estimated to be 0.7 mm) after notching is barely visible. A millimeter scale was photographed with the valve. c) Replicate peel photomicrograph of the sectioned ventral margin showing the annulus formed soon after marking (arrow) and four annuli formed thereafter. A metric scale is included.

ing operation, the annulus formed soon after it was marked, and four annuli thereafter (Fig. 3a). This clam and the small individual were captured before the annuli for 1983 had formed. Annuli appear as dark wavy lines at the valve edge, but become more condensed thin lines back into the valve, conditions typical for large, old clams. The annuli were identified as prismatic microstructures in Scanning Electron Microscope (SEM) examinations (Ropes et al. 1984). Growth increments have a light granular appearance under a light microscope consistent with a predominantly homogenous microstructure of ocean quahog shells. The very fine microstructural units are not evident under a light microscope.

The same features seen in the peel of the large ocean quahog occur in the peel of the small individual, except that the growth increments between annuli are more extensive and the annuli are typically non-wavy condensed lines (Fig. 4c). A peel of the hinge tooth shows the same pattern of condensed annuli and growth increments for the small individual (Fig. 4b).

SUMMARY

Despite procedural modifications, the production of acetate peels remains labor-intensive and time-consuming. It is the only known method of producing accurate age data for large ocean quahogs, and selected samples have provided significant information on the age/growth phenomena of the ocean quahog. *Arctica* has been characterized as a slow growing, long-lived bivalve [a 225-year-old individual may be the oldest recorded bivalve (Ropes and Murawski 1983)] and it is not uncommon to capture individuals 100 years old. The frequent occurrence of old individuals complicates application of the method on a population-wide basis.

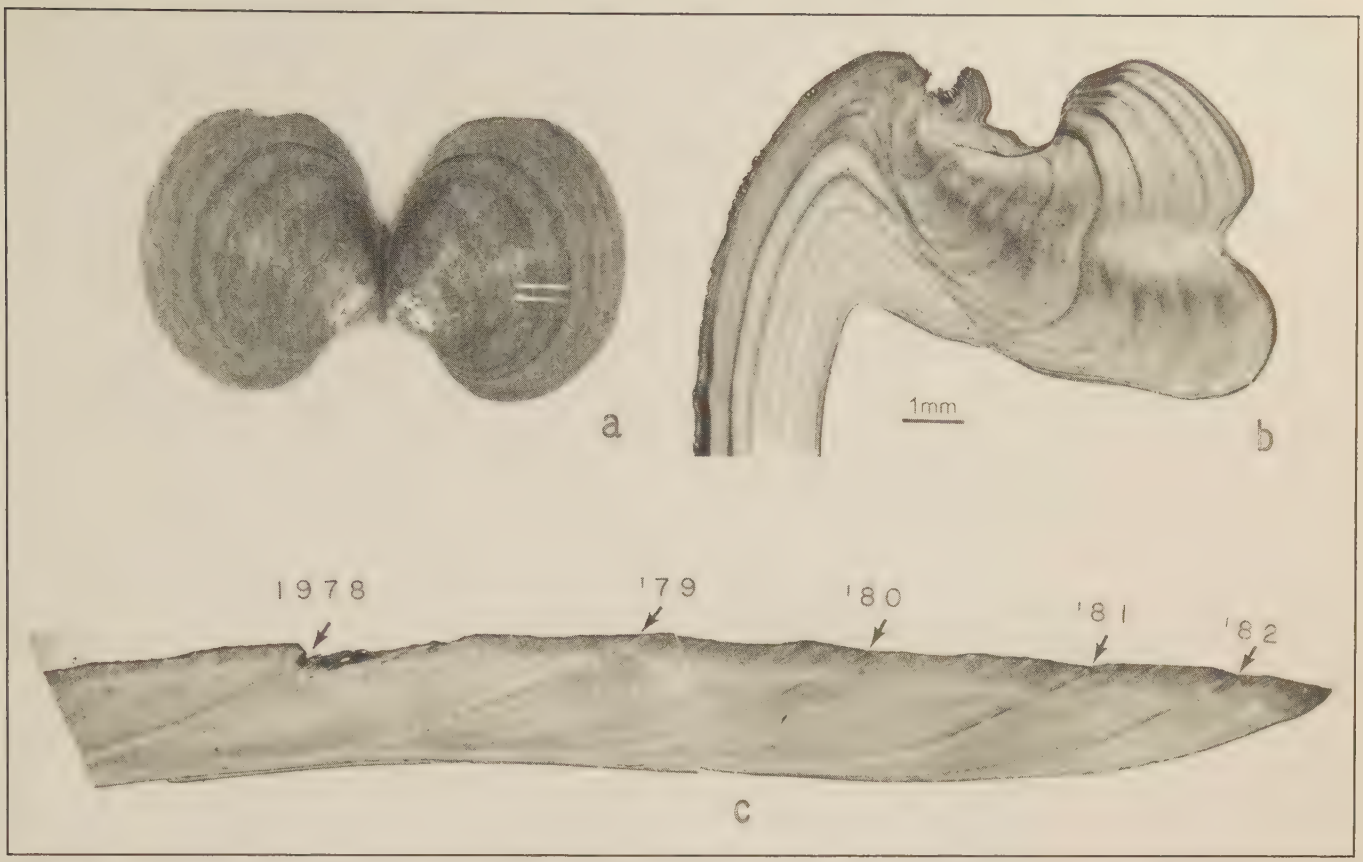

Figure 4—a) A 62-mm shell length ocean quahog, *Arctica islandica*, marked in 1978 and recaptured in 1983. Paired parallel notches clearly delimit growth (estimated to be 14.4 mm) after marking. b) Eleven annuli are shown in the photomicrograph of the clam's hinge tooth. These corresponded to the same number of annuli found in the valve. c) Replicate peel photomicrograph of the sectioned ventral valve margin showing an annulus that had formed soon after marking and four annuli formed thereafter. Each annulus is identified by the year of its formation. A millimeter scale applies to peel replicate photomicrographs b and c.

CITATIONS

BENNETT, J. T., K. K. TUREKIAN, W. J. SHAUL, and J. W. ROPES.
1982. Using natural radionuclides to measure shell growth rates and ages of the bivalves *Arctica islandica* (Linné) and *Panope generosa* Gould. J. Shellfish Res. 2:88-89.

CARRIKER, M. R.
1979. Ultrastructural effect of cleaning molluscan shell with sodium hypochlorite (Clorox). Nautilus 93:47-50.

FEDER, H. M., and A. J. PAUL.
1974. Age, growth, and size-weight relationships of the soft-shell clam, *Mya arenaria*, in Prince William Sound, Alaska. Proc. Natl. Shellfish. Assoc. 64:45-52.

JONES, D. S.
1980. Annual cycle of shell growth increment formation in two continental shelf bivalves and its paleoecologic significance. Paleobiology 6:331-340.

KENNISH, M. J., R. A. LUTZ, and D. C. RHOADS.
1980. Appendix I. Preparation and examination of skeletal materials for growth studies. Part A: Molluscs. 1. Preparation of acetate peels and fracture sections for observation of growth patterns within the bivalve shell. *In* Rhoads, D. C., and R. A. Lutz (eds.), Skeletal growth of aquatic organisms, p. 597-601. Plenum Press, N.Y.

KUMMEL, B., and D. RAUP (editors).
1965. Handbook of paleontological techniques. W. H. Freeman, San Francisco, 852 p.

MERRILL, A. S., J. A. POSGAY, and F. E. NICHY.
1966. Annual marks on the shell and ligament of the sea scallop, *Placopecten magellanicus*. Fish. Bull., U.S. 65:299-311.

MURAWSKI, S. A., J. W. ROPES, and F. M. SERCHUK.
1982. Growth of the ocean quahog, *Arctica islandica*, in the Middle Atlantic Bight. Fish. Bull., U.S. 80:21-34.

ROPES, J. W., and L. O'BRIEN.
1979. A unique method of aging surf clams. Bull. Am. Malacol. Union Inc., p. 58-61.

ROPES, J. W., and S. A. MURAWSKI.
1983. Maximum shell length and longevity in ocean quahogs, *Arctica islandica* Linné. ICES/C.M. 1983/K:32, Shellfish Comm., 8 p.

ROPES, J. W., D. S. JONES, S. A. MURAWSKI, F. M. SERCHUK, and A. JEARLD, Jr.
1984. Documentation of annual growth lines in ocean quahogs, *Arctica islandica* Linné. Fish. Bull., U.S. 82:1-19.

STEVENSON, J. A., and L. M. DICKIE.
1954. Annual growth rings and rate of growth of the giant scallop, *Placopecten magellanicus* (Gmelin), in the Digby area of the Bay of Fundy. J. Fish. Res. Board Can. 11:660-671.

THOMPSON, I., D. S. JONES, and D. DREIBELBIS.
1980a. Annual internal growth banding and life history of the ocean quahog, *Arctica islandica* (Mollusca: Bivalvia). Mar. Biol. (Berl.) 57:25-34.

THOMPSON, I., D. S. JONES, and J. W. ROPES.
1980b. Advanced age for sexual maturity in the ocean quahog, *Arctica islandica* (Mollusca: Bivalvia). Mar. Biol. (Berl.) 57:35-39.

TUREKIAN, K. K., J. COCHRAN, Y. NOZAKI, I. THOMPSON, and D. S. JONES.
1982. Determination of shell deposition rates of *Arctica islandica* from the New York Bight using natural ^{228}Ra and ^{228}Th and bomb-produced ^{14}C. Limnol. Oceanogr. 27:737-741.

WEYMOUTH, F. W.
1923. The life-history and growth of the Pismo clam (*Tivela stultorum* Marne). Fish. Bull. Calif. 7, p. 1-120.

WILBUR, K. M., and G. OWEN.
1964. Growth. *In* Wilbur, K. M., and C. M. Yonge (eds.), Physiology of mollusca, p. 211-242. Acad. Press, N.Y.

NOAA TECHNICAL REPORT NMFS

Guidelines for Contributors

FORM OF MANUSCRIPT

Authors are encouraged to retain manuscripts on word processing storage media, such as diskettes, floppy disks, cassette or magnetic tapes, and submit a hard copy run from the storage media. Hardcopy should be typed double-spaced on white bond paper in the following sequence:

Title page
Contents
Abstract
Text
Acknowledgments
Citations
Text footnotes
Appendix
Tables
Figure Legends
Figures

CONTENTS OF MANUSCRIPT

Contents. Contains all text headings with page numbers omitted.

Abstract. Not to exceed one double-spaced typed page. Should include a sentence or two explaining to the general reader why the research was undertaken and why the results should be viewed as important. Abstract should convey the main point of the paper and outline the results or conclusions. Footnotes and references do not belong in the abstract.

Text. A brief introduction should portray the broad significance of the paper. The entire text should be intelligible to readers from different disciplines. All technical terms should be defined. Follow the *U.S. Government Printing Office Style Manual*, 1984 edition.

Fishery nomenclature follows the American Fisheries Society Special Publication No. 12, *A List of Common and Scientific Names of Fishes from the United States and Canada*, 4th edition, 1980.

Abbreviations and symbols. Define all symbols, abbreviations, and acronyms. Define all symbols in equations and formulas. Abbreviate units of measure only when used with numerals or in tables and figures where there is lack of space. Periods are rarely used except for et al., vs., e.g., i.e., etc.

Measurements should be expressed in metric units. Other equivalent units may be given in parentheses.

Text footnotes. Type on a separate sheet from the text. Footnotes are not used for reference material or personal communications, but rather to explain or define terms in the text and for contribution numbers.

Personal communications are noted in parentheses in the text (name, affiliation, brief address including zip code, month and year).

Citations. All written sources should be listed in the Citations section, including unpublished and processed material. In text, cite as Smith and Jones (1977) or (Smith and Jones 1977); if more than one citation, list chronologically (Smith 1936; Jones 1975; Doe 1977). All sources cited in the text should be listed alphabetically by the senior authors' surname under the heading CITATIONS. Abbreviations of periodicals and serials should conform to the Biosis Data Base™. The author is responsible for the accuracy of all citations.

Acknowledgments. Gather all acknowledgments into a brief statement at the end of the text. Give credit only for exceptional contributions and not to those whose contributions are part of their normal duties.

Tables. Tables should supplement, not duplicate, the text. Each table should appear on a separate page, and be numbered consecutively. Headings should be short but amply descriptive so that the reader need not refer to the text. For values less than 1, zeros should precede all decimal points. Give each column a heading with units of measure indicated in parentheses. Do not change the unit of measure within a column. Table footnotes should be numbered consecutively in Arabic numerals across the page from left to right and down; to avoid confusion with exponents, place them to the left of numerals, e.g., $^{3}10$. All tables should be cited consecutively in the text and their placement, where first mentioned, indicated in the left-hand margin of the manuscript page. Lengthy tables that are typed in the proper format and are clean and legible can be used camera-ready.

Figures. Photographs and line drawings should be of professional quality—clear and concise—and reducible to 42 picas for full-page width or to 20 picas for a single-column width, and a maximum of 57 picas high. All illustrations must be proportioned so that they are legible when reduced to fit the page format. Line weight and lettering should be sharp and even. Lettering on graphs should be upper and lower case, and vertical lettering should be avoided as much as possible (except for vertical, y, axis). For values less than 1, zeros should precede all decimal points. Reproductions of line art work are accepted in the form of photographic prints from negatives or photomechanical transfer. Halftones should be sharply focused with good contrast. Micron rules should be inserted on electron micrographs, even when magnification is included in the figure legend. There should be good distinction between identifying letters (preferably press-on) and background of photograph. All figures should be cited consecutively in the text and their placement, where first mentioned, indicated in the left-hand margin of the manuscript page. Each figure should be labeled in pencil on the back. DO NOT SEND original or photographic prints of figures to the Scientific Editor; they will be requested when the manuscript is accepted for publication.

Copyright. Government publications are in the public domain, i.e., they are not protected by copyright.

SUBMISSION OF MANUSCRIPTS

Send original hardcopy and two duplicated copies of the manuscript to:

Dr. Andrew E. Dizon, Scientific Editor
NOAA Technical Reports NMFS
Southwest Fisheries Center
National Marine Fisheries Service, NOAA
P.O. Box 271
La Jolla, CA 92038-0271

Indicate whether word processing storage media are available, but do not forward disks until requested by Scientific Editor or Scientific Publications office.

Copies of published reports. For single monographs, the senior author will be provided with 50 copies free of charge and 50 to his or her organization. For collections of papers, each senior author will receive 50 separates and one cover, and his or her organization will receive the same. Additional copies may be purchased in lots of 100.

ADDITIONAL INFORMATION

Questions regarding editorial policy and procedures may be forwarded to:

Nancy Peacock, Managing Editor
NOAA Technical Reports NMFS
National Marine Fisheries Service, NOAA
Scientific Publications Office
Bin C15700
Seattle, WA 98115

UNITED STATES
DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC
ADMINISTRATION
NATIONAL MARINE FISHERIES SERVICE
SCIENTIFIC PUBLICATIONS OFFICE
BIN C15700
SEATTLE, WA 98115
OFFICIAL BUSINESS

Penalty for Private Use, $300

BULK RATE
POSTAGE & FEES PAID
U.S. Department of Commerce
Permit No. G-19

NOAA SCIENTIFIC AND TECHNICAL PUBLICATIONS

The National Oceanic and Atmospheric Administration was established as part of the Department of Commerce on October 13, 1970. The mission responsibilities of NOAA are to assess the socioeconomic impact of natural and technological changes in the environment and to monitor and predict the state of the solid Earth, the oceans and their living resources, the atmosphere, and the space environment of the Earth.

The major components of NOAA regularly produce various types of scientific and technical information in the following kinds of publications:

PROFESSIONAL PAPERS—Important definitive research results, major techniques, and special investigations.

CONTRACT AND GRANT REPORTS—Reports prepared by contractors or grantees under NOAA sponsorship.

ATLAS—Presentation of analyzed data generally in the form of maps showing distribution of rainfall, chemical and physical conditions of oceans and atmosphere, distribution of fishes and marine mammals, ionospheric conditions, etc.

TECHNICAL SERVICE PUBLICATIONS—Reports containing data, observations, instructions, etc. A partial listing includes data serials; predictions and outlook periodicals; technical manuals, training papers, planning reports, and information serials; and miscellaneous technical publications.

TECHNICAL REPORTS—Journal quality with extensive details, mathematical developments, or data listings.

TECHNICAL MEMORANDUMS—Reports of preliminary, partial, or negative research or technology results, interim instructions, and the like.

Information on availability of NOAA publications can be obtained from:

U.S. Department of Commerce
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161